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Myopia and Refractive Error in Dogs

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The refractive error of 240 phakic dogs of various breeds was measured using streak retinoscopy and averaged (−0.27 ± 1.41 D relative to infinity). Analysis by breed showed that the German Shepherd, Rottweiler, and Miniature Schnauzer breeds had an increased prevalence of myopia with an average refractive error of −0.86 ± 1.31 D, −1.77 ± 1.84 D, and −0.66 ± 1.05 D, respectively. Myopia also was found in older dogs with marked nuclear sclerosis of the crystalline lens. Fifty-three percent of all German Shepherd dogs in a veterinary clinic population (n = 58 eyes) had a myopic refraction of ≥ −0.50 D; 64% of all Rottweiler dogs (n = 28 eyes) were myopic. An in-depth investigation of German Shepherd dogs, using A-scan ultrasonography, photokeratoscopy, and streak retinoscopy, was done at Guide Dogs for the Blind (San Rafael, CA). By contrast with the results obtained in the veterinary clinic population, the overall average refractive error of guide dog German Shepherd dogs (n = 106 eyes) was +0.19 ± 0.81 D, and only 15% of these dogs were myopic. The axial length and corneal curvature of myopic eyes did not differ significantly from nonmyopic eyes. Invest Ophthalmol Vis Sci 33: 2459–2463, 1992

In recent years, various animal models of myopia have been reported. In the avian chick model, marked amounts of myopia have been induced by occlusion[1] and optical blur.[2] The induced myopia occurs independently of intact optic nerve function[3,4] and despite lesioning of the Edinger-Westphal nucleus.[2,3] Occlusion myopia also has been found in several species, including tree shrews, macaques, cats, and rats,[5–8] and humans.[9]

The relevance of these models to the human condition lies primarily in understanding the underlying fundamental mechanisms whereby myopia occurs. In looking at human clinical correlates, these models are most applicable to cases of neonatal form-deprivation myopia (eg, resulting from hemangioma, congenital cataract, or ptosis). By far, the most common form of myopia in humans is juvenile myopia; this occurs at 6–14 yr of age and is typified by refractive errors between −1.00 and −5.00 D.[10] Animal models are not strictly comparable to human juvenile myopia in the areas of age of onset, magnitude of the myopia which develops, and degree of sensitivity to environmental manipulation. By contrast with these deprivation models, naturally occurring models of animal myopia are rare; however, there are anecdotal reports of myopia in animals, although the validity of some of these accounts is questionable. For example, the kiwi was reported to be uniformly myopic,[11] but recent retinoscopic measures document these birds to be hyperopic when manually restrained.[12]

While conducting a survey of refractive error in dogs, we discovered that myopia (≥ −0.50 D) not associated with sclerotic changes of the crystalline lens was present in only three of the breeds examined: German Shepherd, Rottweiler, and Miniature Schnauzer. In this article, we describe the distribution of refractive errors in 11 breeds of dog. In addition, we compared the refractive error in a veterinary clinic population of German Shepherd dogs with the refractive error in a specialized population of service dog (ie, German Shepherd dogs trained by Guide Dogs for the Blind [San Rafael, CA]). We also conducted a preliminary investigation of the ocular components by comparing corneal curvature and axial length in emmetropic and myopic guide dogs.

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Materials and Methods

Optical Methods

Streak retinoscopy was done on dog eyes by refracting both horizontal and vertical meridians using a lens bar at a working distance of 67 cm. For the nonguide dogs, a single refractionist obtained all values. For the guide dogs, each animal was examined by two refractionists to assess the accuracy and repeatability of the retinoscopic result. For nonguide dogs, most animals were refracted after cycloplegia with topical cyclopentolate 1% to determine the effect of cycloplegia. Thirty dogs were refracted both without and subsequently with cycloplegia.

Corneal curvature was measured by photokeratoscopy. The photokeratoscope consisted of eight fiberoptic light guides surrounding a 50-mm 1.2 f-stop Nikkor lens (Nikon) attached to a Nikkor PK-3 extension ring. The apparatus, calibration, accuracy, and evaluation techniques have been described previously.[13,14]

A-scan ultrasonography was done using a Storz Biometric Ruler (Storz, St. Louis, MO). This device employs a solid-state A-scan probe and provides a graphic oscilloscope and a digital readout of axial length.

Animals

Two populations of dogs were examined in this study. The first population consisted of dogs that were patients at the Veterinary Medical Teaching Hospital, University of California (Davis, CA) and the Sacramento Animal Medical Group (Carmichael, CA). Dogs were not excluded specifically from refractive examination, except where temperament or ocular disease precluded an accurate refraction. Dogs were chosen without regard to age or sex. Streak retinoscopy was the only technique done on this population.

The second population consisted of all juvenile and adult German Shepherd dogs kenneled at a Guide Dogs for the Blind facility (San Rafael, CA). All underwent cycloplegic streak retinoscopy, photokeratoscopy, and A-scan ultrasonography. Cycloplegia was achieved by the instillation of two drops of cyclopentolate 1% 30 min before examination.

Data Analysis

Data were analyzed by breed, age, and sex. Mean and standard deviation were computed for each breed that contained five or more dogs. The terriers were analyzed as a single group, although several separate breeds were included. Likewise, mixed-breed dogs were analyzed as a single group, although many different lineages were included.

German Shepherd dogs were analyzed as two separate populations (guide dogs and nonguide dogs) and as a single pooled group. Nonparametric statistical analysis using the Wilcoxon rank-sum test was done to determine the significance of the myopia identified in the Rottweiler, Miniature Schnauzer, and German Shepherd breeds. Student t-test was used to compare corneal curvature and axial length between myopic and emmetropic guide dogs, and multiple-regression analysis was done on ocular component data. In all instances, P values greater than 0.05 were regarded as statistically not significant.

Results

Table 1 summarizes the mean refractive error found for each of the 11 groups of dogs. Thirty-nine dogs showed at least 0.50 D of anisometropia. Ten animals had astigmatism of at least 0.50 D (range, 0.50–3.00 D); eight of them were astigmatic in only one eye. We found 160 eyes were at least 0.50 D hyperopic, with 52.5% of them in the range 0.50–0.99 D and 43.1% in the range 1.00–2.00 D. Retinoscopic refractions were unaffected by the state of cycloplegia. In no animal was a refractive shift of ≥ 0.12 D detected after cycloplegia was induced.

The distribution of refractive error in the Rottweiler, Miniature Schnauzer, and German Shepherd dogs is shown in Figure 1. The mean refractive error of the Rottweiler dogs was -1.77 ± 1.84 D (range, +0.75 to −5.00 D). The frequency of myopia was 64% with the average refractive error in this group being -2.89 ± 1.27 D. A clear familial tendency toward myopia was identified; entire families were affected. Neither age nor sex correlated with refractive error.

The Miniature Schnauzer dogs' average refractive error was -0.67 ± 1.05 D (range, +0.50 to −2.00 D). Fifty percent were myopic (mean, -1.50 ± 0.65 D). Four of the myopic dogs were from one family. The German Shepherd nonguide dogs' mean refractive error was -0.86 ± 1.31 D (range, +1.00 to −4.75 D).

Table 1. Refractive error for 11 breeds of dog

Breed	*Number of dogs*	*Mean (D)*	*Standard deviation (D)*
German shepherd	30	−0.86	1.31
Guide dog	53	0.22	0.79
Chesapeake Bay retriever	5	0.83	0.73
Cocker spaniel	7	0.10*	0.77
Golden retriever	5	0.40	0.67
Labrador retriever	14	0.63	0.70
Mixed breed	8	−0.38	0.86
Poodle	9	−0.38*	0.81
Rottweiler	14	−1.77	1.84
Miniature schnauzer	8	−0.67	1.05
Shar pei	7	0.11	0.79
Springer spaniel	5	0.17	0.39
Terrier	17	−0.02	1.58

* Eyes with marked nuclear sclerosis were deleted from analysis for these breeds. Including animals with marked sclerotic lenses in the analysis (cocker spaniel, n = 1, and poodle, n = 2) resulted in a mean refraction of −0.59 diopters (D) −1.13 D, respectively.

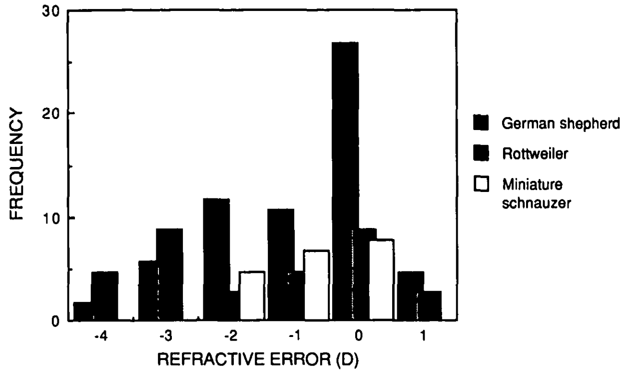

Fig. 1. Profile of refractive error in three breeds of dog with marked myopia—German shepherd, rottweiler, and miniature schnauzer.

Fifty-three percent were myopic. The mean refractive error of myopic eyes was −1.93 ± 1.06 D. By contrast, German Shepherd guide dog had a mean refractive error of +0.22 ± 0.79 D (range, +1.50 to −2.50 D); 10 of 53 (19%) animals were myopic. Myopic animals had a mean refractive error of −0.90 ± 0.89 D.

Average corneal curvature among German Shepherd guide dogs was 36.67 ± 1.35 D (range, 33.78–39.66 D) with 9.20 ± 0.67 mm (range, 9.99 to 8.50 mm). The average axial length among guide dogs was 21.92 ± 0.54 mm (range, 20.7–22.9 mm). There was no significant difference in either corneal curvature or axial length between myopic and emmetropic guide dogs. Figure 2 plots the refractive error against the corneal curvature in all guide dogs (r = 0.03), and Figure 3 plots the refractive error against the axial length in guide dogs (r = 0.03). Multiple regression of refractive error on corneal curvature and axial length showed no significance for either term ($P = 0.80$ and 0.77, respectively, by Student's t-test).

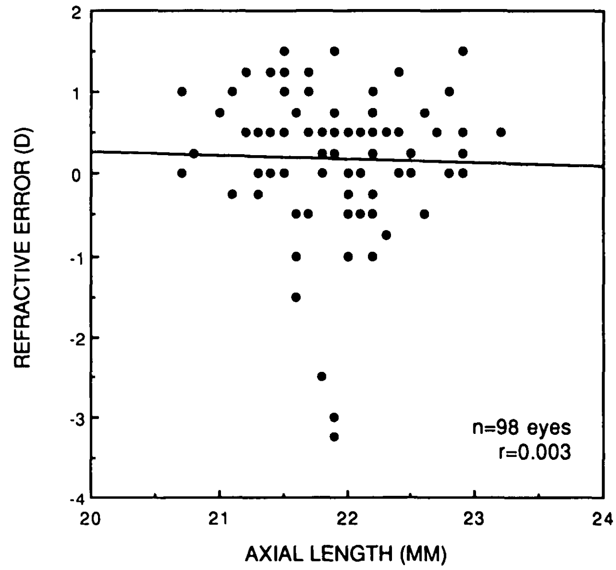

Fig. 3. Refractive error as a function of axial length in 98 eyes of guide dog german shepherds.

A bivariate plot of age and refractive error is shown in Figure 4. There was a statistically significant correlation between age and refractive error that was especially evident in the older animals.

Discussion

Early researchers, obtaining measurements from anatomic specimens, reported the axial length of the canine eye to be 21.73 mm on average and the mean

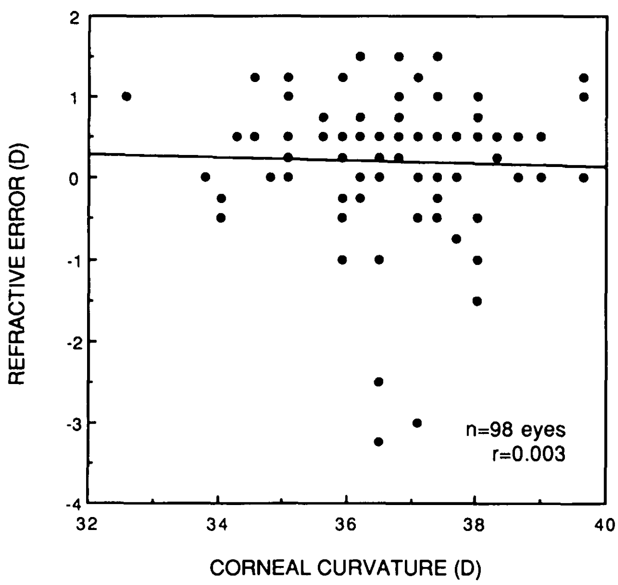

Fig. 2. Refractive error as a function of corneal curvature in 98 eyes of guide dog german shepherds.

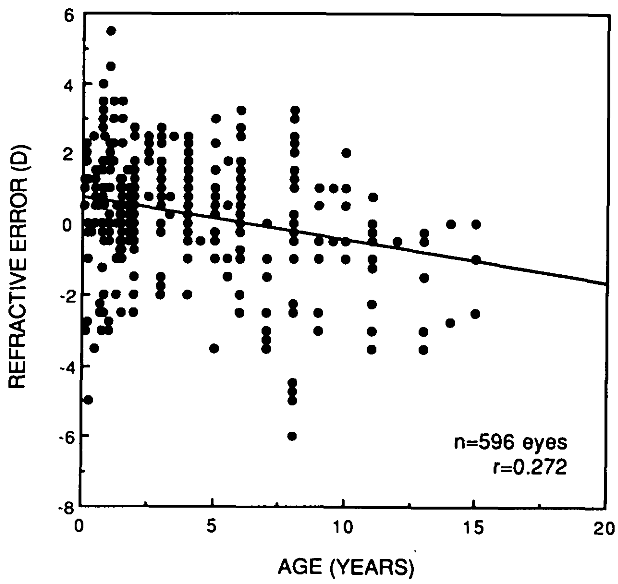

Fig. 4. Refractive error as a function of age in 596 eyes of various breeds of dogs.

corneal curvature to be 39.71 D (8.5 mm; range, 37.50–42.19 D or 8.0–9.0 mm).[15] Early reports on the resting refractive state of the dog varied widely in their findings. The refractive state was measured in 100 dogs of various breeds, and dogs were reported to be uniformly myopic with a mean refraction of −3.00 D (range, −1.50 to −6.00 D). These values were not affected by topical application of atropine.[16] Others, reporting on 106 dogs of various breeds, found the refractive state to vary widely, with myopia being the most common (range, 2.00 to −4.50 D). Most myopic animals had −0.50 D of myopia, and a small number of astigmatic dogs were identified.[17] In a limited survey of 12 dogs, most were myopic (range, 0.00 to −2.25 D) with 18 of 24 eyes being ≥ 0.50 D myopic. Three of the 12 dogs had ≥ 0.50 D of anisometropia.[18] Hyperopia was reported to predominate (0.50–1.50 D being typical) in another study, and myopia was found to be rare in breeds other than the Pekingese dog.[19]

Modern reports of refractive error in dogs have indicated slight hyperopia on average. A mean refractive error of +0.50 D was found with a mean corneal radius of curvature of 8.77 mm (38.50 D) and a mean axial length of 20.9 mm in 50 eyes of various breeds of dog. No significant difference was reported between cycloplegic and noncycloplegic retinoscopic results.[20] Others found similar values for axial length and corneal curvature[21–23] but reported differences with various breeds and head conformations.[20] Emmetropia to low myopia was found with infrequent astigmatism or anisometropia in 85 dogs in another study.[24]

We investigated 11 breeds of dog and 240 animals; our results agreed with these previous published reports (Table 1). The nuclear sclerotic changes observed in some older dogs were associated with a myopic shift in refractive error (Fig. 4). Overall, the statistical correlation between age and refractive error was significant ($r = 0.272$, $P < 0.0001$). Similar findings have been shown in some humans,[25] but the magnitude of this shift in the general population was insufficient to result in an increased prevalence of myopia late in life.[26]

Myopia (at least −0.50 D, on average) was found in only three breeds of dog. The prevalence of myopia in all other breeds was 24% compared with a prevalence in excess of 50% in German Shepherd, Rottweiler, and Miniature Schnauzer dogs. A marked increase in the prevalence of myopia in these breeds suggests a familial tendency for the development of myopia in the dog. In the Rottweiler and Miniature Schnauzer breeds, entire families were affected; other families were completely free of myopia.

Guide dogs had a significantly lower prevalence of myopia (34% less) than the prevalence of myopia in nonguide German Shepherd dogs. The reason for this is not obvious. We speculate that the rigorous selection process, which excludes an animal for any aberrant or less than optimal performance, selected against any dog whose visual performance could be compromised for any reason. It should be noted, however, that the visual performance of dogs with myopia has not been evaluated critically to our knowledge.

Our analysis of ocular components, done on German Shepherd guide dogs, suggests that the myopia is of lenticular origin because no significant differences in corneal curvature or axial length were found between myopic and nonmyopic animals and no linear relationship was found between the ocular components and refractive error (Figs. 2, 3).

Typically, juvenile-onset myopia in humans is characterized by an elongation of axial length relative to the anterior refracting elements of the eye.[27] Its onset is typically during the elementary school years with cessation of progression near puberty.[10] The role of inheritance in the development of human juvenile myopia is a hotly debated topic. The basic arguments raise the issue of the relative role of nature and nurture in the development of juvenile myopia. Studies of ocular component concordance in twins[28] and siblings[26–28] provide evidence for a genetic element; other population studies across generations invoke an environmental influence.[29–33]

The prevalence and public health significance of juvenile myopia in humans have stimulated the search for animal models. Recently, the chicken has become the most intensively studied animal in this regard.[1–4] The strength of the chick model is that the results are reproducible and that the myopia produced is associated with vitreal chamber elongation. As a model for human juvenile myopia, the chick model has several shortcomings (eg, the magnitude of myopia in the chicken far exceeds that found in human juvenile myopia, the model requires physical disruption of the visual image, the chicken eye can recover after myopia induction if normal vision is restored, and there are marked differences between the anatomy and physiologic optics of avian and human eyes).[34–37]

The occurrence of myopia in dogs holds promise for future study as a spontaneously occurring mammalian model for human juvenile myopia. This report documents the prevalence and magnitude of spontaneously occurring myopia in an at-large canine population. Our data strongly suggest that there is a heritable component to this condition in dogs.

Similar to human juvenile myopia, canine myopia occurs at a relatively low frequency and is of relatively low magnitude. In the one breed of dog in which the ocular components were measured, the data suggest a lenticular origin for the myopia observed. These data are preliminary, and an axial component could be responsible for the myopia observed in other breeds.

Key words: dog, keratoscopy, optics, myopia, refractive error

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